The Independent Readiness Team (IRRT) of SMC

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The Independent Readiness Review Team (IRRT) performs risk assessment of space launch missions and reports findings in pre-launch reviews to SMC Leadership. To date, the IRRT has performed reviews on the Evolved Expendable Launch Vehicle (EELV) Atlas V and Delta IV boosters, Heritage boosters such as Titan II, Delta II and Minotaur, and payloads including DSP, GPS, SBIRS, DMSP, Milstar, AEHF, WGS and selected space test programs. Since the inception of the IRRT, SMC has experienced an unprecedented 46 straight mission successes in a row.

I. Introduction

The history of Mission Assurance at Space and Missile Command (SMC) is that independent review teams were formed close to mission launch to perform reviews of large launch vehicles. These teams, which consisted of Air Force, Aerospace and contractors would review the mission, present their risk assessment and then be disbanded. During Acquisition Reform of the mid 1990s, SMC eliminated Independent Reviews although NRO retained their Mission Assurance Team (MAT) for launch vehicles.

In the late 1990's, the Air Force experienced repeated failures of Delta II and Titan IV systems. These failures were attributed to the lack of discipline that resulted from Acquisition Reform. In 2001, Lt. General B. Arnold SMC/CC reformed and reconstituted the independent review process for SMC missions in response to the succession of Broad Area Reviews (BAR) conducted subsequent to the failures.

The primary change from previous independent reviews was the formation of a standing team, The Independent Readiness Review Team (IRRT), to perform readiness reviews of both space launch vehicles and payloads. The IRRT was made independent of all two-letter organizations and reported directly to the SMC commander. The IRRT was given its own annual budget funded by the System Program Offices through the above standard cost mechanism.

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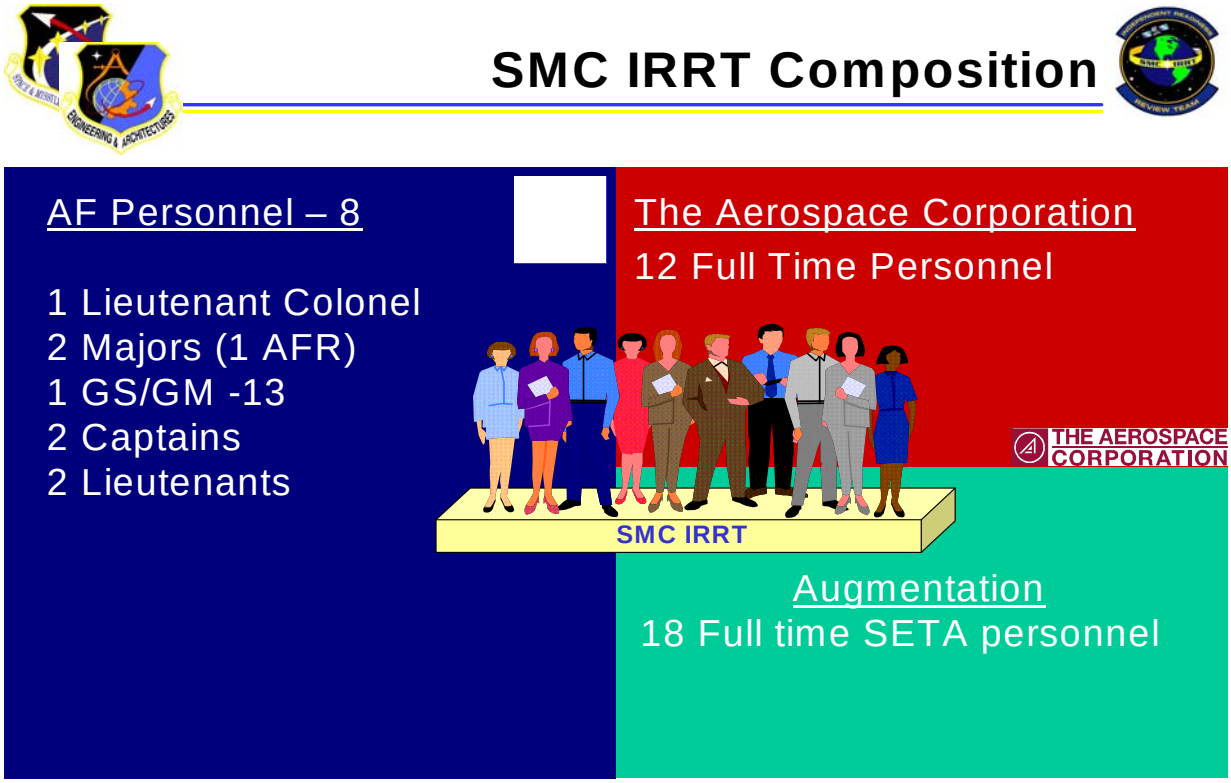
The IRRT charter is to perform independent reviews of Air Force satellite acquisition and launch missions as directed by SMC/CC. The reviews are performed to support the SMC Space Flightworthiness Certification process as dictated by SMCI 63-1201, Assurance of Operational Safety, Suitability & Effectiveness (OSS&E) for Space and Missile Systems, and defined in SMCI 63-1202, Space Flight Worthiness. Other documents describing the review process are SMCI 63-1203, Independent Readiness Reviews, and SMCI 63-1204, Readiness Review Process. The objective of the reviews is to identify technical risks, make recommendations for mitigation and to provide independent assessment of launch readiness. The IRRT formally presents the results at periodic reviews and reports directly to SMC Leadership.

To fulfill its charter, the IRRT follows a number of guiding principles. The IRRT strives always to be value added to the SPO, SMC/CC and the Chief Engineer. This is accomplished in a number of ways including 1) a proactive and phased review that leverages existing SPO processes, and, 2) the maintenance of strong communication links including regular status briefs to ensure early identification of issues and concerns. The benefit of this approach is that it raises IRRT identified issues early in the process while adequate time exists prior to mission launch to allow recommendations to be implemented. Cost is also minimized since the majority of IRRT reviews are inline with the SPO, thus eliminating the need for costly separate reviews.

II. IRRT Organization

The IRRT consists of Air Force, Aerospace and SETA contractors as shown in Figure 1 below. The IRRT is billeted for one Lt. Col who acts as the Chief, four full-time Majors and two Lieutenants. The Aerospace Corporation has ten full-time employees in the IRRT program office including the Vice-Chief. Additionally, Aerospace has support, on an as-needed basis, from their Engineering and Technology Group (ETG). Finally, the IRRT receives substantial support from three SETA contractors, Northrop Grumman (NGC), SAIC, and ARINC.

The IRRT is a matrix organization with both System and Panel Leads that are responsible for accomplishing the required reviews. The system leads are responsible for the review of a specific system and are given budget authority and resources to accomplish the required tasks. The panel leads support multiple system leads in specific disciplines such as propulsion, avionics, software, mechanical/structural, etc. To illustrate how the IRRT functions, consider a typical review of the Delta II launch vehicle. The system lead responsible for Delta II will request support from each of the panels to perform reviews, identify any issues and assist in preparation of risk charts. The panels that support the Heritage System Lead include propulsion, structures, avionics, software and product assurance. Each panel lead will request support in performing the required reviews from the appropriate engineers supporting the specific panel. The propulsion panel reviews will include the Graphite Epoxy Motors (GEM), which are the solid strap-on motors and the stage 1 RS-27 and stage 2 AJ-10 liquid Engine Pedigree Reviews. Booster integration reviews may also be supported by propulsion. The results from the reviews performed by each panel are forwarded to the system lead. He converts them into risk charts. These charts are reviewed and approved by the IRRT Chair and Vice-Chair prior to release to the Delta SPO and SMC leadership.



6

Figure 1. The standing team of the SMC IRRT is composed of Air Force, Aerospace, Northrop-Grumman, SAIC and ARINC engineers.

III. IRRT Review Approach

The IRRT employs a team approach to all review activities that includes 1) Review of SPO and contractor data focusing on the high risk areas, 2) Participation in program processes, 3) Utilization of a clearly defined issue identification and resolution process, and, 4) Closure and risk assessment.

The IRRT review of SPO and contractor documentation focuses on a number of items as discussed below that are believed to pose the greatest risk to the success of space launch missions. By focusing efforts on the high-risk items, the IRRT can identify issues of concern in a cost-effective manner.

1. Test as you fly exceptions

   One of the most important lessons learned in the space launch business is the necessity to perform tests or analysis of hardware and software in the same manner the mission is flown. Exceptions to test as you fly have resulted in past flight failures and represents an increased program risk that must be appropriately addressed.

2. Critical Qualification Margins

   Qualification margins of critical items are of high importance. Hardware that has minimal margins of safety poses an increased risk to failure due to variations in mechanical properties, performance or other critical measures. Hardware with

large margins has rarely been associated with mission failure, thus requiring less review.

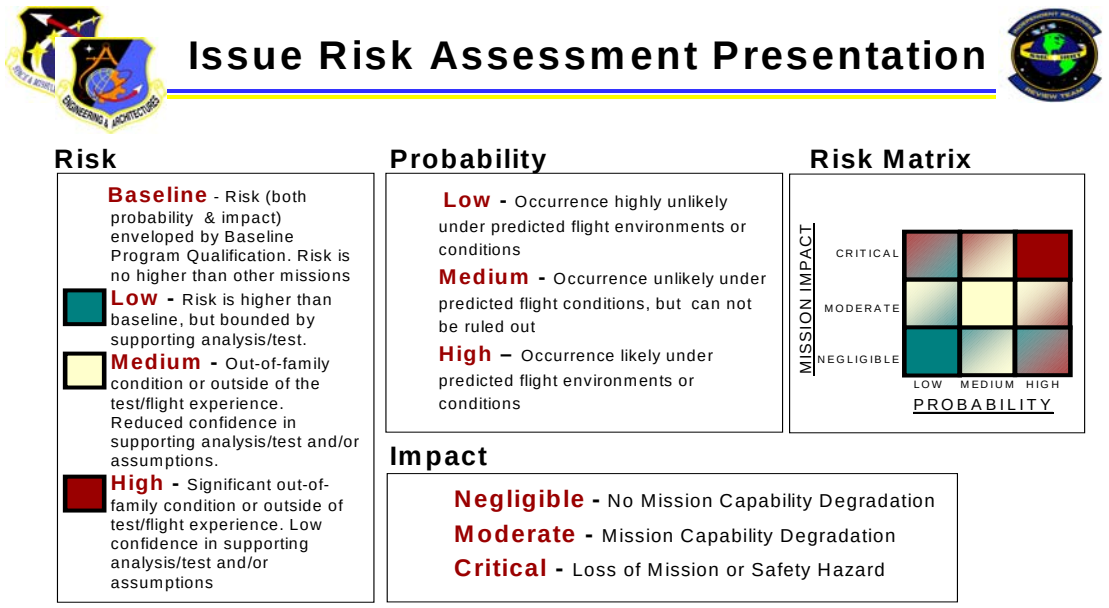
3. First flight items
   First flight items receive increased scrutiny simply because they have not been demonstrated to work under actual flight conditions. The IRRT requests a list of first flight items at each review along with a clear description of the qualification performed to ensure the first flight item will perform adequately.
4. Single point failures
   Redundancy in a system is desired since it significantly reduces the probability of failure. Potential single point failures must be carefully scrutinized to ensure an adequate level of quality.
5. Non-conformances
   Non-conformances occur when hardware or software does not meet the specification requirements. In some instances, the item will be reworked to correct the discrepancy while in other instances it will be recommended, “use as-is”. A review of the specific actions performed and the contractor justification is considered a high priority. The IRRT has identified instances where contractor justification to Use-as-is was inadequate resulting in replacement of questionable hardware.
6. Anomalies
   Anomalies represent situations where hardware or software did not perform as expected. Careful review and test or analysis is required to verify the anomaly will not occur or will not have a significant impact on the mission for which the reviews are performed.
7. Escapements
   Escapements represent an event wherein the contractor missed something such as releasing hardware that did not receive all of the required testing. The IRRT strives to identify any escapements as part of the pedigree review and hardware acceptance review process. Once identified, escapements are reviewed carefully to assess the likely impact on mission performance and recommendations are made for corrective action. This may include test or analysis or simply use as-is.
8. Unverified Failures
   Unverified failures are instances when failures occur and root cause is not identified. Unverified failures are of concern since confidence in hardware or software fixes is low if the root cause of the problem cannot be identified. These failures are of most concern when there is potential for mission failure.
9. Out-of-position/ Sequence (OOPS) work
   Occasionally, contractors will deviate from their paperwork and perform work out of sequence. This may result in errors in the product that need to be addressed or test results that are invalid. The IRRT reviews such errors to evaluate impact on the mission and provides recommendations for corrective action.
10. Out-of-family results
    Out-of-family results are carefully reviewed since they often indicate that something has changed in the process. Statistical Process Control (SPC) is an effective means to identify out-of-family results.

The IRRT is unique for a review team in that it participates in the program processes. The IRRT supports 1) Technical Interchange Meetings, 2) Integrated Product Team Meetings, 3) Hardware Acceptance Reviews (HARs), 4) Pedigree Reviews, and 5) Design Reviews. The IRRT follows the SPO and contractor processes and provides opinions and recommendations for consideration. We support problem resolution and failure investigation activities as appropriate such as nozzle delamination investigations and SRM redesign activities. The benefit is the IRRT has both input and insight into the SPO and contractor actions as opposed to teams that perform reviews after the fact. Despite its interaction with the SPOs and the contractors, the IRRT remains independent with careful adherence to its processes and procedures.

The IRRT follows a clearly defined issue identification and resolution process. This includes inline process participation as noted previously and formal submission of requests for information, RFIs, and concerns. The IRRT maintains an extensive database documenting all identified issues and resolution to allow virtual collaboration and to retain lessons learned. The use of SETAs has also proven useful since these companies often bring knowledge and experience to bear in problem resolution that otherwise would not be available. For instance, Northrop Grumman has over 40 years of ICBM experience that has been useful in the resolution of problems with SRM nozzle defects and the SRM design issues. The IRRT maintains close communication through weekly status reports that identify current risk ratings, issues and scheduled meetings. Closure of RFIs is performed in a formalized manner by the team leadership and typically involves internal technical meetings.

IV. IRRT Deliverables

The IRRT examines selected parts, components, subsystems and subsystem pedigree documents for compliance and evidence of risk. Formal risk assessment charts are generated for each identified issue and the scale for assessing risk is shown in Figure 2 below. The chart includes a risk matrix with probability of occurrence on the x-axis and mission impact on the y-axis. The IRRT probability ratings run from Low to High. Low probability indicates the occurrence is highly unlikely, Medium means an occurrence cannot be ruled out, and High indicates an occurrence is likely. Each of the ratings is based on an assessment assuming predicted flight environments or conditions. Intermediate scores such as Low-Medium are allowed where appropriate. The mission impact categories are Negligible meaning no mission capability degradation, Moderate for mission capability degradation, and Critical for loss of mission or safety hazard. The risk ratings are Baseline, Low, Medium and High with intermediate ratings allowed as noted previously. Baseline risk means that both probability and impact are enveloped by the baseline program qualification. Risk is no higher than on other missions. Low means that risk is higher than Baseline but is bounded by supporting test and/or analysis. Medium refers to an out-of-family condition or out of test/flight experience. There is reduced confidence in supporting tests and/or analysis and in the inherent assumptions. High represents a significant out-of-family condition or outside of test and/or flight experience. Low confidence exists in supporting test and/or analysis and the inherent assumptions.



11

Figure 2. The IRRT uses this chart for assessing risk for issues raised during our reviews.

A program risk quad chart is presented to the SPO undergoing review weekly. It contains information such as the review plans, schedule and the items in work. Risk reduction recommendations and options are frequently included. This chart is updated weekly to reflect the status of each program. The IRRT maintains a record of all work performed as part of an electronic database. This assists to ensure Lessons Learned and fleet issues are not forgotten. The Issue Risk Assessments and the Program Risk Quad Chart are formally briefed as part of the flight certification process to the SPO, the Mission Director, the Aerospace President, the SMC Chief Engineer and the SMC/CC in various pre-launch reviews. The specific reviews supported are the Mission Readiness Review (MRR), the Aerospace President's Review (APR), and the Flight Readiness Review (FRR).

V. Examples of IRRT Findings

The IRRT has performed reviews on the Evolved Expendable Launch Vehicle (EELV) Atlas V and Delta IV boosters, Heritage boosters such as Titan II, Delta II and Minotaur, and payloads including DSP, GPS, SBIRS, DMSP, Milstar, AEHF, WGS and selected space test programs. There have been numerous findings from these reviews of which the following are samples.

The IRRT Software team identified severe and significant shortcomings in flight software development and execution for an SMC program. It provided a risk reduction roadmap that the SPO adopted and has used to track risk reduction. In addition, the IRRT

uncovered grossly inadequate unit level tests for flight software and recommended remedies that have been implemented by the SPO and contractor.

The IRRT diagnosed the root cause for a failure in a phase lock loop circuit and recommended corrective action to the SPO and contractor that were accepted. By examining schematics, the IRRT engineer identified the location of an open circuit that would cause the behavior observed in test. He visited the contractor's facility where the hardware was stored and examined the location of the hardware that corresponded to the schematic location. He found that the behavior would come and go by pressing on the transistor lead. During the diagnosis of the problem, the team discovered severe workmanship problems that needed corrective action. These problems were corrected, the payload was launched and continues to perform as expected.

The IRRT Structural-Mechanical panel provided recommendations to reduce the risk of telescope contamination cover latch failure. The contamination cover protects a telescope aperture and is a single point failure. The SPO and contractor accepted design and test recommendations from the IRRT to reduce the risk of mission loss.

During booster component reviews, the IRRT identified two motors with suspect nozzles. The first motor had a nozzle that was dropped off a pallet then subsequently installed onto a motor. The IRRT reviewed the motor as part of its normal review process and found the analysis to justify the use of the dropped nozzle to be inadequate since it did not consider dynamic loads. The motor manufacturer and the SPO both agreed that additional work was required to clear the nozzle prior to flight. The second motor had two separate sources of PAN tape used to manufacture the carbon phenolic exit cone liner. One source of tape was used on half of the liner with the other source of tape used for the remainder. The two sources of tape had substantially different mechanical properties that differed by as much as a factor of 2. The motor manufacturer had not done any analysis to determine the effects of the exit cone liner with mechanical properties that changed dramatically midway through the liner. The disposition was to replace the motor and set it aside until an adequate structural analysis of the exit cone liner could be performed.

Another issue found by the IRRT was a lack of SRM traceability to a qualified baseline. To overcome this issue, the IRRT reviewed 11 ship sets, including several that had flown to evaluate risk of flight. The resulting review showed that each change while not necessarily qualified by IRRT standards, was reasonably supported by flight test, analysis or experience from other programs. The launch proceeded with an elevated risk rating and was successful. The IRRT has recommended the contractor show proper traceability to the qualification baseline or perform delta qualifications as needed.

VI. Challenges Forward

For an IRRT to be successful, it needs a senior leadership champion. Six years ago when the team was founded, the IRRT needed the help of the center commander to gain the cooperation of the SPOs that were the targets of the IRRT's reviews. Over the ensuing years, the IRRT has become part of the launch process and an accepted member of the team. As the failures of the 1990s recede into the past and current budgets receive greater scrutiny, there is a danger that mission success may lose emphasis. This happened in the mid 1990s under Acquisition Reform with disastrous results. As noted by Lt. General B. Arnold in his 2004 congressional hearing testimony, "… I want to reiterate the Young Panel and the Space Commission's findings that US National security is

critically dependent on space capabilities and that dependence will continue to grow." Because of the U.S. dependence on communications and intelligence gathering satellites, the OSS&E emphasis including the use of an IRRT must not be marginalized or eliminated.

VII. Summary and Conclusions

The SMC IRRT was established based on the BAR recommendations and the Air Force's desire to refocus on OSS&E. The IRRT has conducted technical reviews on SMC launch vehicles and spacecraft since 2001. SMC/CC and the Board of Directors approve the funding and scope for the IRRT. The IRRT is fully established and uses mature processes that have been demonstrated to be effective. The IRRT has been successful in identifying issues and suggesting mitigations to lower flight risk. The IRRT as part of Team SMC has experienced an unprecedented 46 straight mission successes in a row.